

*kuraray*

# PHOTOVOLTAIC MODULE ENCAPSULATION

ADVANCED SOLAR SOLUTIONS WITH PVB FILM

PRODUCT INFORMATION

**TROSIFOL<sup>®</sup>**



With courtesy of: Fraunhofer ISE, Freiburg/Germany

## TROSIFOL® SOLAR - A NEW DIMENSION IN SOLAR MODULE MANUFACTURING

### ADVANTAGES OF TROSIFOL® SOLAR PVB FILM:

**non-crosslinking thermoplastic**

**excellent adhesive properties on  
glass, solar cells, metals and other  
plastics**

**outstanding optical transparency**

**high bond durability**

**excellent resistance to heat, UV-  
light and environmental influences**

**very high compatibility with module  
components**

**reproducible lamination behaviour  
in all conventional lamination  
processes**

**significant energy savings in logistics  
chain (no need for cooling of film)**

**certified according to IEC 61646:2008  
and IEC 61215:2005**

**can be stored and processed up to  
4 years after manufacture**

TROSIFOL® polyvinyl butyral (PVB) film is a product with decades of successful use in the production of laminated safety glass for architectural and automotive applications. Recent years have seen a sharp rise in the quality and manufacturing efficiency required of photovoltaic (PV) modules and in the importance of high-grade encapsulation materials for the solar cells in the modules. TROSIFOL® has responded to this by becoming the first supplier to develop a new, special PVB film for PV – TROSIFOL® SOLAR.

TROSIFOL® SOLAR can be processed both in conventional vacuum laminators and in the two-stage process used successfully for laminated safety glass. This can take place either in a vacuum de-airing process (for modules with crystalline cells) or a roll lamination process (nip-roll process for thin-film modules) with subsequent autoclaving at elevated pressure and temperature.

TROSIFOL® is certified to ISO/TS 16949:2002, DIN EN ISO 9001:2008, DIN EN ISO 14001:2005 (environmental management systems) and BS OHSAS 18001:2007 for occupational safety & health management systems.



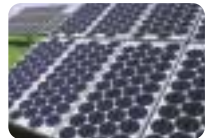
★ **2009**  
Market introduction of multifunctional PVB film (encapsulant + reflection) and next generation TROSIFOL® SOLAR product line.

★ **2007**  
First thin film turn-key factory starts module production with TROSIFOL® SOLAR R40.

★ **2006**  
First serial use of TROSIFOL® SOLAR in thin film modules

★ **2005**  
Market introduction of TROSIFOL® SOLAR, a dedicated PVB film product line for PV applications

★ **1982**  
Manufacture of commercial modules with TROSIFOL® by AEG Solar



★ **1980s**  
Start of first "Jumbo" production TROSIFOL® line (3.21 m width)



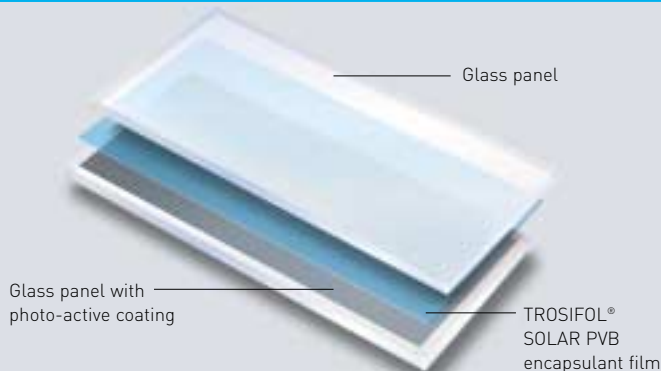
★ **1950**  
Use of laminated glass with PVB film was made compulsory for the automotive industry in North America

★ **1940s**  
Intensified use of laminated glass in car, aviation and building industry

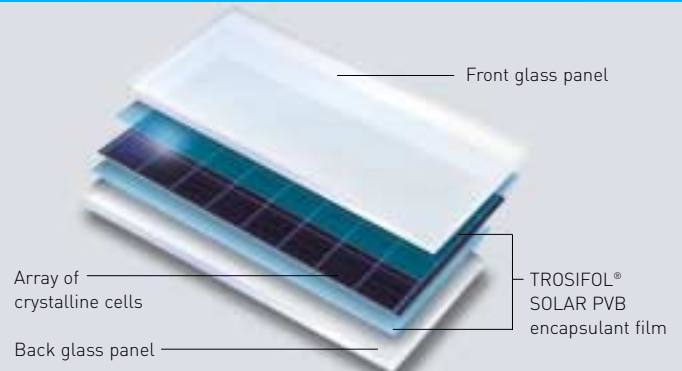
★ **1930s**  
Invention of today's laminated safety glass with PVB film



### PV MODULE – THIN FILM TECHNOLOGY



### PV MODULE – CRYSTALLINE TECHNOLOGY



# LAMINATION PROCESSES FOR TROSIFOL® SOLAR

Depending on the type of cell in the PV module and on the reverse, TROSIFOL® can be processed in one-stage vacuum laminators and, in glass/glass modules, in the two-stage process, i.e. with either the vacuum process or the nip-roll/calender deairing process with subsequent auto-claving.

## RUBBER BAG PROCESS

On the same principle as laminated safety glass, glass/glass modules are preferably deaired in bags made of plastic or rubber and in a vacuum of < 100 mbar in a hot-air oven. The maximum temperature here is about 135°C. The modules are then laminated in an autoclave at elevated temperature and pressure.

## VACUUM LAMINATOR

TROSIFOL® SOLAR – a non-crosslinking thermoplastic – is readily processed in conventional vacuum laminators. The process times is 15-20 minutes for glass/back sheet modules. Cycle time for glass/glass modules is 12-25 minutes, depending on the laminator type and features (standard or multi-stage laminator).

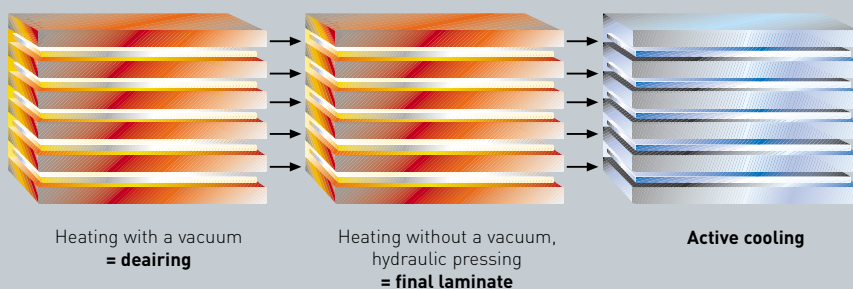


Source: Bürkle GmbH, Freudenstadt/Germany



Vacuum laminator, Source: Swiss Solar Systems AG, Switzerland

## MULTI-STAGE LAMINATOR



### PROCESS CHARACTERISTICS:

Very little edge flow during the laminating process (high edge stability)

Hence no contamination of the glass surface, e.g. by contaminated membranes

Adjustable sandwich deairing rate by using films with different surface roughnesses

Longer service life of laminator membranes and other components/longer oil change intervals

Excellent long-term protection of thin-film modules (Study of an independant PV research institute on CIS modules)



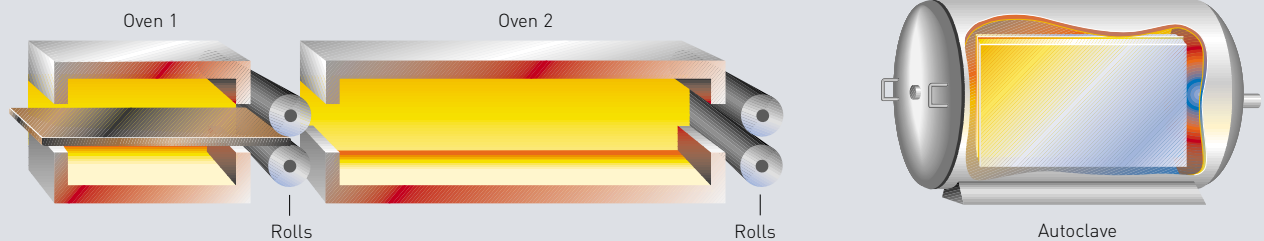
## ROLL LAMINATOR PROCESS

The deairing and subsequent encapsulation of TROSIFOL® SOLAR in the roll laminator process is geared to glass/glass PV modules. This is a highly efficient process with decades of successful use on the industrial scale and is also suitable for coated glass.

It permits high machining speeds, even for large-format modules, and hence high area throughput (cycle time approx. 60 s/module). Depending on the process, nip-roll deairing ovens with one or two IR heating zones and preferably two pairs of rolls are used.

### ROLL LAMINATOR + AUTOCLAVE

Deairing + autoclaving (standard process for laminated safety glass)



#### PROCESS CHARACTERISTICS:

**No edge flow during the lamination process (high edge stability), possibly no need for subsequent trimming**

**Effective process control**

**High area output, larger formats and non-standard module geometries possible**

**High production efficiency and flexibility for glass/glass PV modules**

## AUTOCLAVE PROCESS

In the two-stage process with glass/glass modules, autoclaving is carried out as the second process step.

A pressure of 10-13 bar is set at a holding temperature of 135-145°C, and the process can take between one and two hours, depending on the total glass thickness and cell type even longer. If the autoclave has adapters permitting the generation of the vacuum in the pressure vessel, the initial step can take place here.



Source: Maschinenbau Scholz GmbH & Co. KG

### SUMMARY

#### Laminator process

##### Standard laminator

Process time\*  
24 min

6 modules  
per cycle

##### Multi-stage laminator

Process time\*  
12 min

10 modules  
per cycle

#### Autoclave process

##### Pre-nip process

Cycle time = 60 s/module\*\*

##### Rubber bag

**Pre-lamination:**  
Deairing and  
sealing  
the edges

##### Autoclave

12 bar, 140°C, process time 90 min,  
> 120 modules per cycle

**Lamination:**  
Production of a  
durable laminate

\* depending on module size/structure, Process time reduction possible

\*\* Indicated cycle times are examples of laminator equipment used in PV industry for solar module production.

## OVERVIEW OF TECHNICAL DATA

### PHYSICAL PROPERTIES OF TROSIFOL® SOLAR

Properties	Unit	Test method	SOLAR R40/R100
Density	g/cm <sup>3</sup>	DIN 53479	1.065
Refractive index	-	DIN 53491	1.482
Tensile strength	N/mm <sup>2</sup>	ISO 527	> 23
Elongation at break	%	ISO 527	> 290
Hardness	Shore A	-	65
Melting point	°C	DSC	95-100
Thermal conductivity	W/mK	EN 12939	0.20
Coefficient of thermal expansion	1/K	-	2.2 x 10 <sup>-4</sup>
Resistivity*	Ω x cm	IEC 60093	2 x 10 <sup>12</sup>
UV cut-off	nm	EN 410	375
Visible light transmittance**	%	EN 410	91
Haze	-	-	≤ 0.2
Glass adhesion	N/mm <sup>2</sup>	-	> 17

\* At 0.5% H<sub>2</sub>O content

\*\* LSG made of 2 x 3 mm low-iron glass

Further data available on request



Photo: TÜV certificates of crystalline and thin-film modules

## TEST CERTIFICATES

Depending on the cell type, glass/glass modules with TROSIFOL® SOLAR encapsulation films satisfy all the key system requirements for series-produced modules – in accordance with IEC 61215:05 (2005) for crystalline cells.



Examined according to IEC 61646 and IEC 61730

Solar modules produced with TROSIFOL® SOLAR by various thin film module producers are certified according to IEC 61646:2008 and IEC 61730 at TÜV Rheinland. The UL certification is in preparation.



### TEST LABORATORIES FOR PV MODULE CERTIFICATION\*:

**Fraunhofer ISE,**  
Freiburg/Germany

**TÜV Rheinland Group,**  
Cologne/Germany

**Arsenal Research,** Vienna/Austria

**JRC ISPRA,** Italy

**TÜV InterCert,** Padua/Italy

**AT4 wireless,** Málaga/Spain

**CENER,** Sarriguren, Navarra/Spain

**Arizona Photovoltaic Testing LAB (ASU-PTL),** USA

**Japan Electrical Safety & Environmental Technologies Laboratories (JET),** Tokio/Japan & other places

\* Selection of testing institutes

## PRODUCTS AND LOGISTICS

### TROSIFOL® SOLAR

Product	Colour	Thickness [mm]	Roughness [µm]	Roll length [m]
SOLAR R40	Clear	0.76*	40	250/450
SOLAR R100	Clear	0.76	100	200

\* SOLAR R40 is available on request in other film thicknesses (0.38 mm/1.14 mm); max. width 3210 mm

In Kuraray's corporate philosophy, long-term, future-oriented growth is closely tied to sustainable business processes and the sparing use of limited resources.

The goal of this forward-looking approach is to reduce the impact of emissions on the environment, develop environment-friendly products and select suitable raw materials on the principle of "green procurement".

TROSIFOL® SOLAR products are supplied as standard with a polyethylene interleaf in order to prevent the consumption of additional energy during storage and shipment.\* Furthermore, all TROSIFOL® products are shipped in multi-way packages.

Processing is recommended in a moisture-controlled lay-up room with a relative humidity of 25-30% and at a temperature of 15-20°C.

\* Refrigerated films are also available on demand.

#### ADVANTAGES OF THE PROCESSING OF TROSIFOL® SOLAR:

**TROSIFOL® SOLAR trimmings are collected and preferably recycled - hence environment-friendly**

**PE interleaved PVB film saves energy**

**all packages are taken back and disposed of (within the EU)**

**almost exclusive use of multi-way packages**

## ADVANTAGES OF SAFETY GLAZING WITH TROSIFOL® SOLAR

Glass/glass PV modules for building integration, e.g. for façades, overhead glazing and parapets, have to satisfy specific safety requirements and legal provisions. The film properties therefore have to meet the needs of conventional safety glazing, which also applies when the PV module is integrated in an insulation glazing element.

Glass/glass PV modules manufactured with TROSIFOL® SOLAR PVB film satisfy the highest safety requirements governing glazing in the building envelope.



Ball drop test in accordance with DIN 52338



Pendulum test in accordance with EN 12600

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